INSTRUCTION MANUAL

MILLIVAC INSTRUMENTS

LOAN ONLY

INSTRUCTION MANUAL

TYPE – –

MV-864A

DC Multimeter

SERIAL NO.

MILLIVAC
INSTRUMENTS, INC.
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MILLIVAC
INSTRUMENTS, INC.

MANUAL CHANGES

MODEL NO. MV-864A
TYPE DC Multimeter

SERIAL NO. 2001 and up - Change 1

Change 1:

a. Section 6, Replaceable Parts List and Schematic Drawing No. 864A-2001

Change Q219 to transistor, Ge, PNP, 2N1414 Millivac P/N 100-1008, Manufacturer's P/N GE 2N1414

b. Schematic Drawing No. 864A-2001

Reverse polarity of C401 by mounting it on printed circuit board assembly, A601 in a position opposite to the polarity indicated on circuit board.

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SPECIFICATIONS

ACCURACY	15 Volt ranges	100μV ±3% FS 300μV ±2% FS 1mV - 1000V ±1% FS
	15 Amp ranges	100nA to 1 Amp ±2% FS
	9 Ohm ranges (max. current thru R_X, 10mA)	±10% of reading 0.1 to 0.2 ohm and 500 to 5000 megohms, ±5% of reading 0.2 ohm to 500 megohms
SENSITIVITY		±10μV; ±10nA; 100mΩ
WARM-UP TIME		30 seconds
RISE TIME		less than 1 second
INPUT IMPEDANCE	Voltmeter	100μV to 10mV - 10 meg ±1% 30mV - 30 meg ±1% 100mV -100 meg ±1% 300mV to 1000V-200 meg ±1%
	Ammeter	100nA - 10K, 300nA - 3.3K, 1μA to 10μA - 1K decreasing to .01Ω on 1 Amp range
VOLTAGE DROP		10mV FS on basic ranges
AMPLIFIER	Voltage gain	10,000 maximum
	Hum rejection (at power line freq.)	Min. 60db
	Noise	Less than 2μV RMS (6μV P-P), referred to input
	Drift	Negligible
	Output Voltage	Adjustable from 0 to ±1.0V, FS
	Output Current	±1mA @ 1.0V, depending on setting of output potentiometer
	Output Impedance	Less than 2Ω, also function of output potentiometer's setting
LEAKAGE	(Floating input to ground)	Min. 1000 meg.
FLOATING MODE OPERATION		600V DC or 130V AC above ground
METER		6" taut-band movement with mirror-backed dial
POWER		Approximately 12 watts at 115/230V AC, 50 - 450Hz
DIMENSIONS	Cabinet	9"H, 6-3/4"W, 11-1/2"D
	Rackmount	5-1/4"H, 19"W, 11"D (behind panel)
WEIGHT	Cabinet or Rackmount	12lbs (net), 14lbs (shipping)

SECTION 1

GENERAL DESCRIPTION

1-1 FUNCTION OF THE INSTRUMENT

The MV-864A, DC Multimeter is a solid-state, lightweight and compact instrument. It is an extremely versatile and unique measuring instrument. The voltage measuring range extends from 10μV to 1000V, while the current measuring range extends from 10nA through 1A. The wide-range measuring ability of this instrument makes it ideally suited for both low and high level voltage and current measurements.

The resistance measuring capabilities further add to the usefulness of this instrument as an all-purpose DC Multimeter. It has nine ohm-measuring ranges, and is capable of measuring resistances from 100 milliohms to 5,000 megohms. Special precautions have been taken to assure high accuracy of resistance measurements, as well as very low power consumption across R_X. (See page iV - Specifications).

1-2 UNIQUE INSTRUMENT FEATURES

A. No warm-up time or heat rise due to solid-state circuitry

B. Operates on either 115 or 230V; 50 - 450Hz

C. "HI" and "LO" inputs for selection of chassis grounded or floating operation (See Section 2, Par. 2-1)

D. Adjustable DC output from 0-1V for recorder indication

E. Individual calibration controls for all voltage and most current ranges

F. Carrier frequency of 94Hz is used to insure low-noise performance

1-3 POWER LINE REQUIREMENTS

A selector switch is provided on the rear nameplate to select either 115 or 230V AC operation. The MV-864A can operate from 50-450Hz. Normally the input hum rejection filter is adjusted to 60Hz unless otherwise specified.

1-4 ACCESSORIES FURNISHED

Three sets of test leads are supplied with this instrument. Two of these leads are identical and interchangeable (Part No. UG-201). The third lead, Part No. CL-102, is for the output receptacle only. These test leads utilize solid copper, alligator clips to minimize the effect of thermo-electric voltages when measuring low-level DC signals.

1-5 LIST OF INSTRUMENT CONTROLS

(See Fig. 1-1 and 1-2 on page 3)

A. Front Panel Controls

1. Function Switch - This serves the dual purpose of turning the instrument on while at the same time selecting the mode of operation, either volts, amps, or ohms

2. Range Selector Switch - Enables the operator to select any of the 15 voltage, 15 current, or 9 ohm ranges

3. Mechanical Zero Adjust - Mechanically sets the indicating meter pointer to the Zero position when the meter is de-energized

4. Zero Control - Part of a dual (stacked) control. Electrically zeros the instrument preferably with input leads shorted

5. F.S. Ohms - Part of a dual (stacked) control. Adjusts the meter reading to Full Scale with the function switch in "Ω" position and the input leads open

6. Pilot Light - Indicates when the instrument is energized

7. Input Connectors - These are bayonnet type BNC connectors designated as "HI" and "LO" into which the input signal is fed. (See Section 2, Par. 2-1)

B. Rear Panel Controls

1. Output Connector - Furnishes ±1V DC output @ 1.0mA max.

2. Output Adjust - Varies the output voltage from 0-1V DC @ 1.0mA

3. Line Voltage Switch - Selects either 115 or 230V AC operation

4. Fuse Holder - Contains 0.3 amp "Slo-Blo" fuse

5. Power-Connector for removable three conductor AC line cord

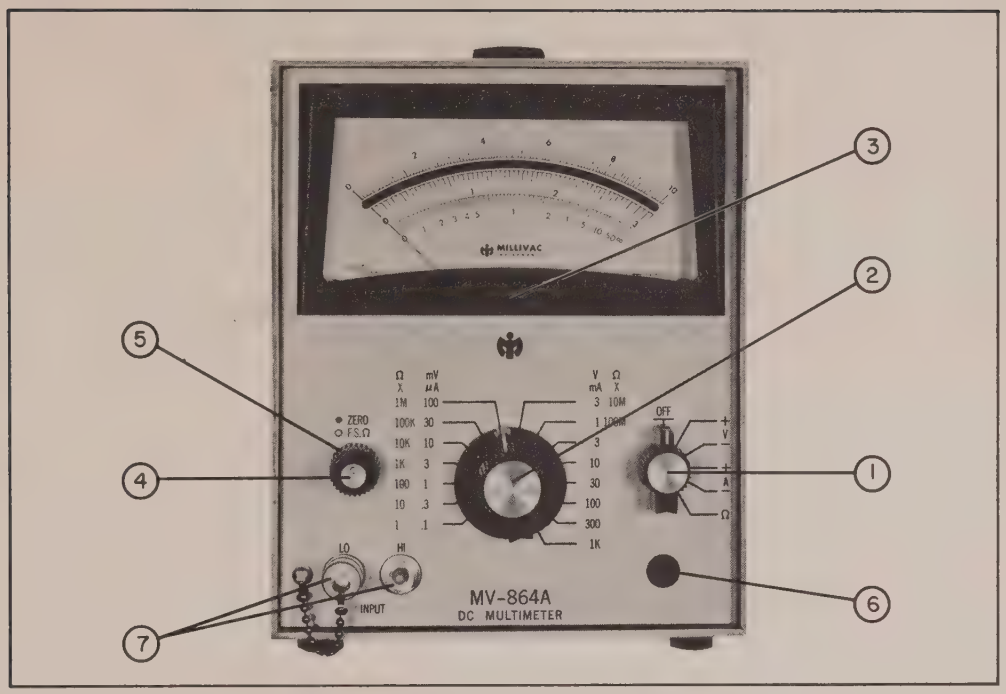


FIG. 1-1 FRONT PANEL CONTROLS

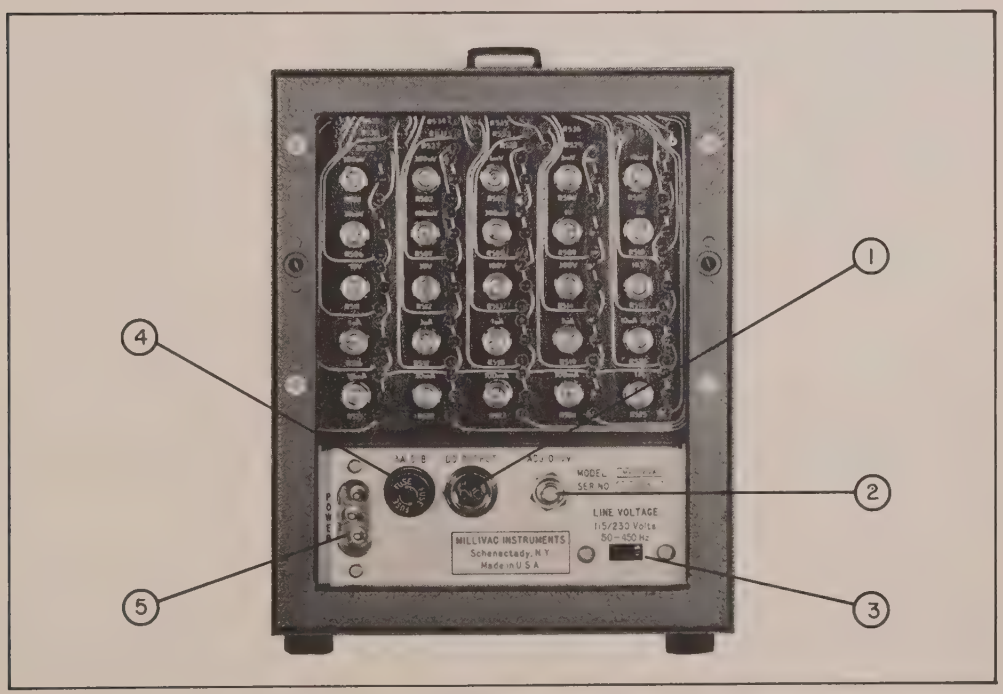


FIG. 1-2 REAR PANEL CONTROLS

SECTION 2

OPERATING INSTRUCTIONS

2-1 OPERATION

After unpacking the instrument and accessories, make certain no concealed damage has been incurred during transit. Check that the LINE VOLTAGE slide switch on the rear of the instrument agrees with the local LINE VOLTAGE. If necessary, it can be changed with the aid of a screwdriver. Prior to turning the instrument on, be sure that the pointer on the indicating meter is at the Zero Position. If necessary, adjustment may be made using the Mechanical Zero Adjust. For normal use connect test lead set (Part No. UG-201) to the input connector marked "HI". Put the shorting cap provided on the input connector marked "LO". When making measurements using this input set-up, always make sure that the black lead, which is electrically connected to the housing and chassis of the meter is attached to a signal-grounded point while the red lead is attached to the signal carrying point, otherwise excessive hum in leads may create erratic readings.

To utilize the floating input characteristics of this instrument, remove the shorting cap from the "LO" input connector and use a UG-201 Test Lead set on each input connector. Short the black coded clips together and use the red coded clips for measurements. Always connect the red coded clip from the "LO" input connector to the point that has the lower potential to ground.

When the desired input connection has been made, turn the instrument on by moving the function switch to either volts for voltage measurements, amps for current measurements, or ohms for resistance measurements. Select the proper range for the measurement to be made and with the voltage or current source de-energized, or in the ohm position, with the input leads shorted, electrically zero the instrument. The instrument is now ready for use.

2-2 GENERAL PRECAUTIONS

The high sensitivity of the instrument requires certain operating precautions which are not, to the same extent, necessary with less sensitive instruments. Any of the three phenomena described below, or any combination of them, may cause considerable off-sets in the indication of the meter. This may easily be mistaken for drifts, noise, or off-sets of the instrument itself, while in reality, the reason may be entirely different. Therefore, the following possible sources of errors should be avoided, or their influence minimized as much as possible.

A. Thermo-Electric Voltages. They are parasitic voltages created through temporary or permanent temperature differences between the various junctions in the measuring circuit, both inside and outside the meter. When calibrating the meter on its more sensitive ranges, or when checking its calibration on these ranges, it is important that the following procedure be observed: Connect the meter to the voltage divider point expected to supply the exact voltage, but leave the power to this divider de-energized until the meter has been carefully zeroed. Then turn the power on and observe the deflection. An alternate but wrong procedure would be to have the attenuator energized before the meter is connected to the signal source and zeroing the instrument with its input terminals shorted.

If thermo-electric voltages exist after connecting the terminals of the instrument to the voltage divider, they would falsify the calibration signal. Therefore, the first method should always be used.

In order to reduce the possibility of thermo-electric voltage errors, the input circuitry of the instrument was designed with special precautions. The input cables have solid copper alligator clips, so that no thermo-electric voltages will be created in the copper wire-alligator clip junction. However, the user must avoid creating additional thermo-couples in the circuitry under test by carefully avoiding any dissimilar metal connections.

B. Hum Signals. Any hum signal will have a tendency to create measuring errors if it is superimposed upon DC voltages to be measured. In order to reduce this error to a minimum, an effective hum rejection filter in the input circuit reduces this source of measuring error considerably. The rejection by this filter to hum signals is 60db minimum on the lowest ranges. As a simple rule, it can be said that a certain DC signal, superimposed by an identical amount of AC pick-up, will be read with an error of less than ±0.1%. Nevertheless, large AC signal content should be avoided when making DC measurements. The hum rejection is further increased on voltage ranges above 10mV due to the resistive divider, which drops any DC voltage to be measured to a basic sensitivity of approximately 10mV. For instance, in the 1KV measuring range, the hum rejection is 120db in addition to the basic 60db, or a total of approximately 180db. On the current and ohm ranges, the 60db hum rejection remains constant on all ranges.

C. Input Overload. Excessive overload may result in damage to the input circuit. Make certain that the values listed below are not exceeded. Maximum potential difference between panel and floating ground must not exceed 600V DC.

TABLE 1 - MAXIMUM ALLOWABLE OVERLOAD

Voltage Range	Max. Input
100μV thru 10mV	50V
30mV	150V
100mV	500V
300mV thru 1000V	1500V

Current Range	Max. Input	Current Range	Max. Input
100nA	1mA	3mA	30mA
300nA	1mA	10mA	100mA
1μA - 10μA	1mA	30mA	300mA
30μA	3mA	100mA	300mA
100μA	10mA	300mA	1 Amp
300μA	10mA	1 Amp	1.5 Amp
1mA	30mA		

D. Ohm Ranges. In order to get accurate readings when measuring low resistances, it is important to use only a UG-201 lead or equivalent. The lowest resistance range has been factory adjusted in order to assure zero-ohm reading with the alligator clips of the UG-201 shorted.

SECTION 3

DESCRIPTION OF CIRCUITRY

3-1 GENERAL

The basic circuitry of the instrument is best understood by reference to the block diagram, Fig. 3-1.

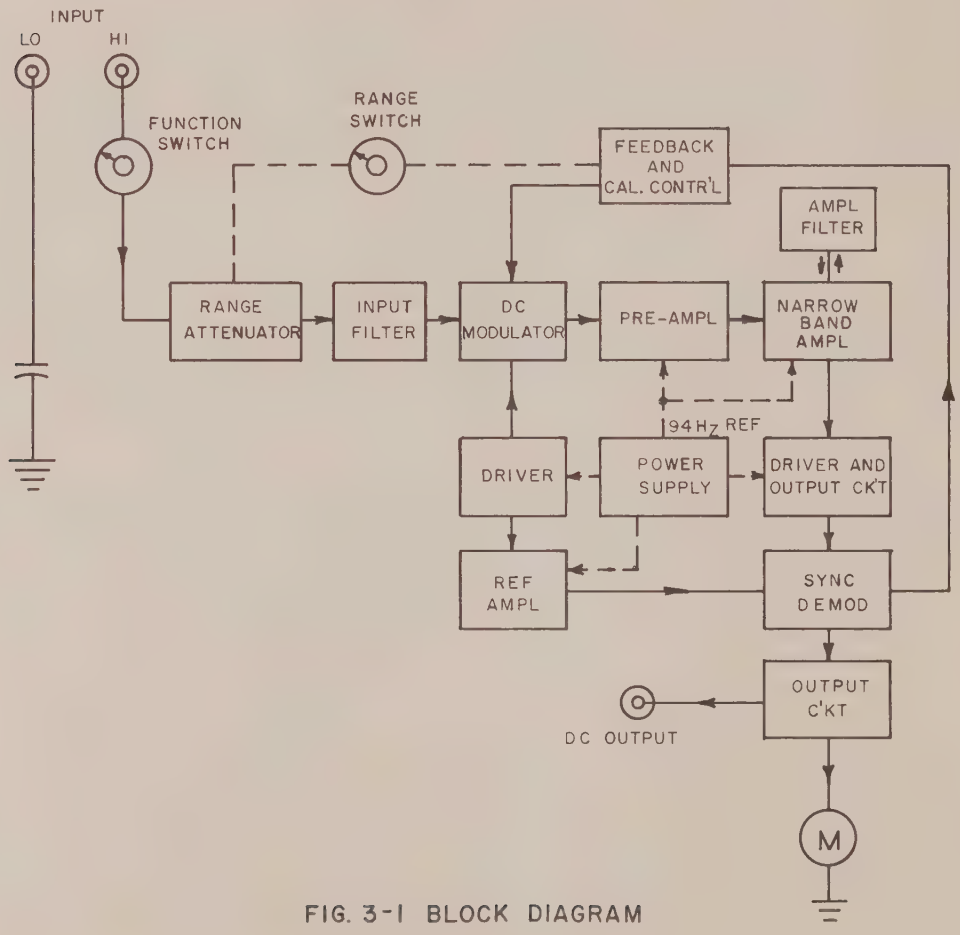


FIG. 3-1 BLOCK DIAGRAM

The DC signal after passing through the function switch and the attenuator section of the range selector switch goes to the Input Filter, for rejection of power line frequency components which might cause a measuring error. A single-pole, double-throw DC Modulator converts the incoming DC signal into a nearly symmetrical square wave. The converted signal is then impedance-matched and amplified by a high impedance Pre-Amplifier. The output from the Pre-Amplifier is fed into the Narrow Band Amplifier, where its narrow band-width improves the signal-to-noise ratio of the instrument. The output of this stage is

further amplified in the Driver and push-pull Class B Output stage. Next, the AC signal is rectified by a Synchronous Demodulator and the resultant DC output is used to provide heavy overall DC feedback. The DC output is also used to drive the indicating meter. The DC Modulator is driven by a two transistor multi-vibrator circuit operating on 14.4 volts from the Power Supply.

The DC Modulator and its Driver circuit determine the carrier frequency (in the order of 94Hz). The square wave output voltage of the Driver is sampled and amplified by the Reference Amplifier whose output is fed to the Synchronous Demodulator. The phase relationship between the Reference Amplifier signal and the carrier amplifier signal determines the polarity of the DC output. An electronically regulated Power Supply delivers 14.4 volts to the amplifier.

NOTE: For the following detailed description of each circuit block, reference should be made to the complete circuit schematic for this instrument attached at the end of the manual.

3-2 INPUT CIRCUIT AND FUNCTION SWITCH

The input signal passes from the input connectors to the function switch, S102. The function switch will then select the proper section of the range selector switch, S101 either the voltage divider for voltage measurements, the current shunts for current measurements, or the resistance network for resistance measurements.

3-3 RANGE SELECTOR SWITCH

The range selector switch, S101, consists of nine sections, A through J. Sections A and B contain resistive dividers for the respective voltage ranges. Sections F and G contain shunt resistors for the current ranges. Sections C, D and E contain resistors for the ohm ranges. Sections J and H contain resistors for the voltage and current feedback circuits.

3-4 INPUT FILTER

This consists of an R/C network and a Twin-T-filter providing an effective hum filter with a minimum of 60db rejection at power line frequency. (See Sect. 5, Par. 5-2.5).

3-5 DC MODULATOR (G201)

A 94Hz printed circuit plug-in DC modulator is employed. It modulates the DC input signal and the resultant AC component is applied to the input of the pre-amplifier circuit.

3-6 PRE-AMPLIFIER AND GAIN CONTROL CIRCUIT

The Pre-Amplifier circuit features a low-noise, high-impedance input achieved by the use of a high quality field effect transistor (Q201). Diode CR201 forms a clamp circuit to protect the input transistor from excessive overload. A two-stage conventional R/C coupled, amplifier consisting of Q202 and Q203, with the input transistor Q201 develops an open loop gain of approximately 40db. The supply voltage is held at -5.8 volts

by zener diode, CR203. The output of the Pre-Amplifier is coupled to the Gain Control Circuit consisting of R238, 239 and 240. This controls the level of the carrier signal fed into the narrow band amplifier.

3-7 NARROW BAND AMPLIFIER AND AMPLIFIER FILTER

The Narrow Band Amplifier improves the signal-to-noise ratio by reducing the amplifier bandwidth. It consists of transistors Q211, Q212 and Q213. Q212 is a common-emitter circuit with a parallel "T" network dynamically tuned to 94Hz in a negative feedback loop from collector to base. Q211 and Q213 are emitter followers, which provide impedance matching and isolation. The "T" filter exhibits high impedance at its resonant frequency rapidly decreasing at off-resonance points. With the filter in series with the negative feedback loop, a selective amplifier results with maximum output occurring at filter resonance frequency. (See Sect. 5, Par. 5-2.5).

3-8 DRIVER AND OUTPUT CIRCUIT

The Driver (Q214) and the Class B Output stage (Q215 and Q216) are conventional transformer-coupled stages. The signal developed in the Output stage is applied to the Synchronous Demodulator, where rectification takes place. Before discussing this stage, an explanation of the DC Modulator Driver and Reference Amplifier is in order.

3-9 DC MODULATOR DRIVER

The Modulator Driver is a two-transistor multi-vibrator circuit. The characteristics of the MODULATOR and DRIVER combination determine the 94Hz carrier frequency. It is fine tuned to the proper carrier frequency at the factory by means of R257A and B. (See Sect. 5, Par. 5-2.4).

3-10 REFERENCE AMPLIFIER

The square wave output of the DC Modulator Driver is sampled by the Reference Amplifier via transformer T204. This amplifier, consisting of Q219, Q220 and Q221 is similar to the Driver and Output stage previously described and is used to develop a reference signal for the Synchronous Demodulator for correct rectification of the output signal.

3-11 SYNCHRONOUS DEMODULATOR

Q222 and Q223 are utilized in this phase-sensitive rectifying circuit. The hum signal from the output stage (Q215 and Q216) is compared with the reference signal from Q220 and Q221. The resultant DC output signal from the demodulator has a polarity corresponding to the original input signal polarity. In this type of operation, the collector current is a function of the collector voltage only and is essentially independent from other transistor parameters. The voltage applied to the base of the transistor acts only as a phase-sensitive reference.

3-12 DC FEEDBACK AND CALIBRATION CONTROLS

A portion of the DC output voltage is fed back to the modulator input circuit to provide the excellent gain stability of the instrument. This feedback ratio is determined by values of the series resistance, connected through Sections J and H of the range selector switch. An individual calibration control for each voltage range, for most of the current ranges is also a part of the feedback loop selected by these sections. The appropriate feedback ratio is automatically selected when the range is chosen. The screwdriver adjusted controls are mounted on an internal panel. They are easily accessible from the rear of the instrument and are readily identified. They are properly set at the factory when the instrument is calibrated. If it becomes necessary to re-calibrate the instrument, the controls may be easily adjusted to restore the rated accuracy. In the ohm position the Full Scale ohms potentiometer controls the amount of DC feedback applied.

3-13 METER CIRCUIT

The indicating meter is rated at 0-500μA DC. It is connected to the output of the Synchronous Demodulator through a 2.0K series resistor, R452, making the total meter circuit resistance approximately 2,200 ohms. An output signal of approximately 1V will drive the meter to full scale. Output filtering is provided by capacitors C401 and C402.

3-14 REGULATED POWER SUPPLY

The electronically regulated power supply includes a 115/230V AC split primary power transformer (T601). Its secondary, in conjunction with the rectifiers (CR601, CR602), is used in a full-wave, center-tapped configuration. The rectifier output is applied to the collector of the series regulator transistor, Q601. The base of Q601 is biased by the temperature stable reference amplifier (Q602). The regulated output voltage appears at the emitter of Q601. An adjustable voltage divider across the output, consisting of R606, R608 and potentiometer, R607, permits adjustment of the output voltage by determining the bias on the transistor portion of Q602.

SECTION 4

CALIBRATION

4-1 GENERAL

The instrument, although being rated as ±1% of full scale on voltage ranges, is calibrated at the factory to a much better accuracy. This is possible due to the fact that most Millivac instruments are provided with a calibration control for each range. These controls facilitate quick and accurate re-calibration and compensate for minor errors due to the possible aging of attenuators or other components. Complete in-cabinet calibration may be made after the removal of the cover plate on the rear of the cabinet.

4-2 CALIBRATION PRECAUTIONS

As mentioned in Section 2-2, in order to avoid mis-calibration of the instrument, extra precautions must be taken. The meter should be zeroed only with the calibration output attached to the input of the instrument while the calibrator is de-energized. This procedure should be followed for both the voltage and the current calibration. Zeroing the meter first and then connecting it to the calibrator may introduce calibration errors.

4-3 VOLTAGE CALIBRATION PROCEDURE

Mechanical zero adjustment should always be the first step in calibration. Before any electrical calibration adjustments are made, a warm-up period of 5 to 10 minutes is recommended.

After the correct voltage for individual ranges has been applied, re-adjust, if necessary, the individual controls marked accordingly. After this procedure has been repeated for all the ranges, check the linearity of the meter on the 1 Volt range by applying 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20% and 10% of the signal on a given range. The meter should indicate the same percentage of the reading within the rated accuracy of the meter (±1% of full scale).

4-4 CURRENT CALIBRATION PROCEDURE

After applying the correct current for each range, adjust the controls for the individual ranges accordingly. In the instrument, the 100nA 300nA, and 1μA, 3μA, 10mA, 30mA, 100mA, 300mA and 1 Amp ranges have individual calibration controls, while the ranges from 10μA through 3mA have one common control. This is the reason why the current ranges are rated as being ±2% of full scale, although the ranges with individual controls can be adjusted to better than ±1% accuracy.

4-5 OHM RANGE CALIBRATION

Each ohm range may be checked for accuracy as follows: With the input leads open, adjust the indicating meter to full scale using the "FS Ω" control. Connect across the input leads an accurate calibrating resistance (0.1% or better) having the proper value for the range to be checked. The meter will then indicate the resistance value desired. On the 1 and 10Ω ranges, it will also be necessary to short the input leads and zero the instrument prior to adjusting the "FS Ω" control.

SECTION 5

MAINTENANCE

5-1 GENERAL

The following sections describe the usual maintenance procedure for the instrument.

5-2 MAINTENANCE OF THE INSTRUMENT

5-2.1 Cabinet Removal

Should the instrument require repairs which necessitate its removal from the cabinet, remove the rear calibration cover plate exposing 4-flat head Phillips 6-32 screws. Upon removing these screws (see Fig. 1-2 on Page 3) slide the cabinet to the rear and off the instrument.

5-2.2 General Trouble-Shooting

If the instrument fails to turn on, check the line cord and fuse. The fuse is located on the rear nameplate and should be replaced only with a 0.3A "Slo-Blo" type fuse.

The printed circuit boards may be partially removed from the chassis after removing the 6-32 screws securing them to the chassis frame.

If the instrument is not functioning properly and requires trouble-shooting, the DC Modulator and transistors should be checked first, preferably by substitution. When checking the transistors by substitution, replace only with units of the same type and manufacture. Transistor Q201 may be ordered directly from Millivac, as can the DC Modulator, G201. When the instrument is turned on, the Modulator should produce a continuous audible 94Hz tone. If no tone is evident, the Modulator or its Driver circuit may be defective. Important static-voltage values and waveshapes with peak-to-peak voltage values are shown on the circuit schematic.

5-2.3 Signal Tracing

Assuming that a routine investigation by substitution has confirmed that the DC Modulator and all transistors are good, signal tracing is the next approach.

Recommended service equipment consists of:

1 - DC VTVM, Millivac MV-77B or equal
1 - Tektronix Model 503 scope or equal
1 - AC VTVM (RMS), Millivac MV-45A or equal

When operating the instrument removed from its cabinet, care must be exercised in avoiding power line hum pick-up in the Modulator and Pre-amplifier circuits.

Excessive pick-up will prevent making correct gain and waveshape measurements. If pick-up is a problem, aluminum plates placed on the bottom, top, and amplifier sides of the instrument will effectively shield it.

Be certain that the power supply voltage is set at 14.4 volts before making any gain measurements or variations may result.

A. Checking Waveshape of Complete Amplifier. If the meter is operative at all, although somewhat erratic or intermittent, improper Modulator action or other amplifier weaknesses may be detected by observation of the modulated and amplified signal at the secondary winding of the output transformer, T203 at test point, TP24 or TP26 and chassis ground. (See circuit schematic - Main Amplifier section). A check of the output waveshape can be made by feeding a 100μV D.C. signal into the input with the range switch in the 100μV position and the Function Switch in the Volts position. Without any input signal and the instrument properly zeroed, the waveshape appears as shown in the circuit schematic - Main Amplifier section. The residual signal appearing in the zero-signal waveshape is not entirely amplifier noise. Its spikes and depressions are caused by the 94Hz reference signals impressed upon the bases of Q222 and Q223. Any drastic deviations of either waveshape indicates a faulty amplifier. Improper adjustment of the Zero control may result in large deviations from the waveshapes illustrated.

The reference amplifier output signal must be of the correct amplitude and waveshape for proper operation. The waveshape can be observed across TP27 and TP28. If the scope is tied to the power line, the instrument should be isolated from ground. The waveshape and amplitude should agree closely with that shown on the circuit schematic - Reference Amplifier section.

B. Checking Modulator and Pre-Amplifier Stages. Locate test point, TP22 in pre-amplifier circuit and unsolder the jumping wire connected to it from TP23. This disconnects the output of the Pre-amplifier from the Main amplifier. The waveshape of the amplified, modulated signal at TP22, can be observed, as seen on the Pre-amplifier section of the circuit schematic. Having disconnected the jumper wire, but before making this waveshape measurement, adjust the indicating meter to zero, using the Zero Control.

Two waveshape values are shown. One is with zero-input signal while the other is with a 100μV DC signal applied to the input. With 100μV DC input, the output of the Pre-amplifier should be approximately 100mV, peak-to-peak at 94Hz and should be essentially a square wave. Any drastic deviation in amplitude and waveshape indicates an abnormality in this portion of the instrument. Transistors are checked best by substitution. Be certain to replace only with units of the same type and manufacture.

C. Checking the Main Amplifier Stages. With the amplifier set-up as in 5-2.3B, feed a signal from test set-up as shown in Fig. 5-1, which furnishes the necessary input signal to drive the meter to full scale in the 100μV position. In making this

measurement, the Reference amplifier must be functioning properly with the correct output amplitude and waveshape, as shown on circuit schematic. With the test source switched off, carefully adjust the Zero Control to zero the instrument. Now switch on the test source, supplying the correct input signal to the Main amplifier via TP23. The meter should now slowly move upscale and if the amplifier has the correct gain, the meter will read approximately full scale. If the reading is in error by more than ±10% of full scale, the amplifier Gain Adjust control, R239 can be adjusted for a full scale meter reading. This adjustment should occur at a point between 25% and 75% of the control's rotation.

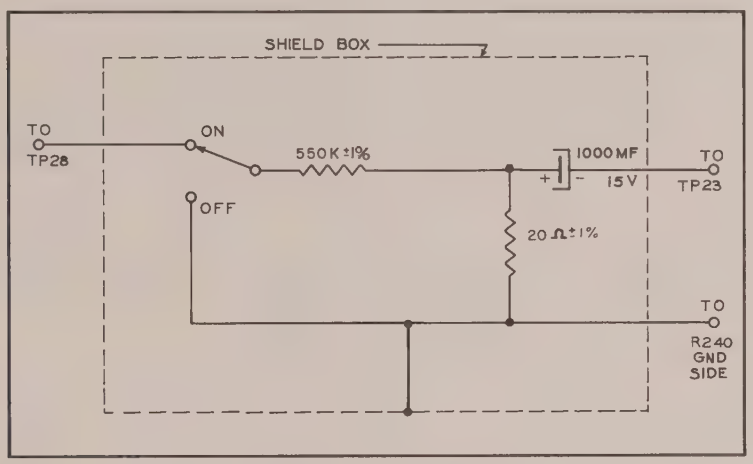


Fig. 5-1 Test Set-Up

If excessive gain is necessary or the meter cannot be made to read full scale, it indicates a faulty amplifier and the transistors in the associated circuit should be checked. It is important to replace only with the same type and manufacture.

When the above adjustments are correct, the instrument can be restored to its normal condition by re-soldering the jumper wire to test point TP22. The instrument's calibration should be checked before placing it back in service.

5-2.4 Modulator and Driver Circuitry

A printed circuit plug-in type Modulator is employed in this circuit. It must be replaced only by a unit of the same type and manufacture. It is recommended that it be obtained from Millivac, where they are tested and checked for performance in Millivac Instruments. The modulator is secured by a hex nut accessible on the printed circuit side of the board directly underneath the Modulator.

The Driver circuit consists of a two-stage multi-vibrator network factory adjusted to achieve a 94Hz carrier frequency. To check the amplifier carrier frequency, observe the output waveshape at TP24 using an oscilloscope. The scope

should be externally triggered by an accurate 94Hz signal source. Next, feed a positive input signal to the instrument, sufficient to drive the meter to full scale and adjust R257A until the waveshape on the scope is synchronized. Since the Narrow-band Amplifier filter differs from instrument to instrument, it may be necessary to re-adjust R257A slightly to obtain a symmetrical square wave similar to the one shown on the schematic at TP24.

5-2.5 Input Filter and Amplifier Filter

The input and amplifier filters are checked at the factory and should not require any maintenance.

The input filter is checked for rejection of power line frequency and has between 60 and 70db rejection. If retuning of the filter becomes necessary, the carbon resistors shunting R203, R204 and R205 should be removed and new values selected.

The amplifier filter is checked for rejection of 94Hz and has a minimum rejection of 50db. If retuning becomes necessary, the carbon resistors shunting R246, R247 and R248 should be removed and new values selected.

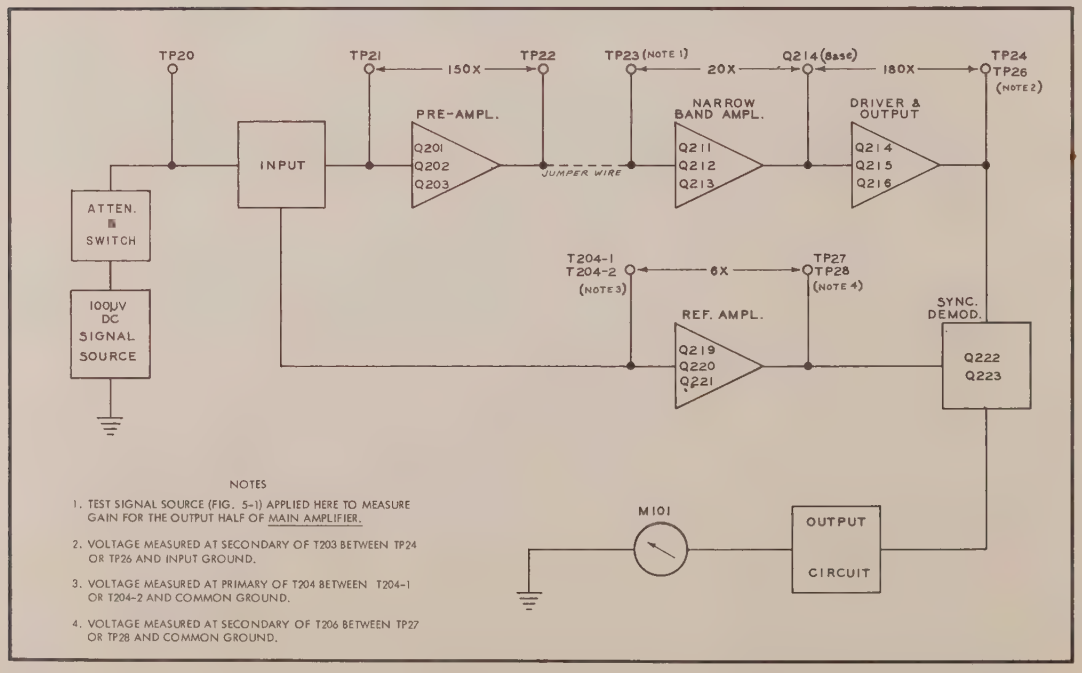


Fig. 5-2 Amplifier Gain Diagram

5-2.6 Power Supply

The output of the power transformer T601 is rectified by diodes CR601 and CR602 in a full wave center-tapped configuration. The resultant DC is limited by R603 and regulated by the series transistor Q601. The adjustable voltage divider R606, R608 and potentiometer R607 sets the bias on the voltage Reference Amplifier Q602, whose output controls the bias on Q601, the series regulator. The output of the power supply can be varied from approximately 11 volts to 18 volts by R607. With the instrument as the only load (approximately 95mA) and the voltage set to 14.4 volts, the power supply should regulate with as little as approximately 80 volts AC input. When measuring the power supply ripple with an oscilloscope, be certain the line voltage is near 115 volts AC. The ripple voltage waveshape is shown on the circuit schematic - Power Supply section. The scope should be connected to TP61 with the ground connection at power supply ground.

SECTION 6

REPLACEABLE PARTS LIST

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
A1 thru A200	Not assigned		
A201	Ass'y, etched circuit board, Main Amplifier	450-1032L	
A202 thru A500	Not assigned		
A501	Ass'y, etched circuit board, Calibration Controls	450-1033D	
A502 thru A600	Not assigned		
A601	Ass'y, etched circuit board, Input-Output, Power Supply	450-1034L	
BT1 thru BT100	Not assigned		
BT101#	Ass'y, battery	460-1001	
C1 thru C100	Not assigned		
C101	Capacitor, paper, mylar, .47μfd, 600V	621-1008	Mallory PVC6047
C102 & C103	Not assigned		
C104 & C105	Capacitor, ceramic, disc, .01μfd, 1000V	610-1017	Centralab C1-103
C106 thru C200	Not assigned		
C201 & C202	Capacitor, paper, mylar, .0047μfd, 200V	621-1023	TRW 663UW
C203	Same as C201		
C204	Capacitor, paper mylar, .01μfd, 200V	621-1024	TRW 663UW
C205	Same as C201		
C206	Capacitor, polystyrene, .01μfd, 400V	622-1002	Arco 4PT-103J
C207 thru C209	Not assigned		
C210	Same as C206		
C211	Capacitor, electrolytic, 2000μfd, 16V	635-1026	Whale 34-750-2000-16-6PC
C212	Capacitor, electrolytic, 100μfd, 16V	635-1017	Richey 14-437-100-16C
C213	Same as C212		
C214	Not assigned		
C215 thru C217	Same as C212		

#Used in Model MV-964A only

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
C218 thru C240	Not assigned		
C241 & C242	Same as C212		
C243	Capacitor, ceramic, GMV, .003μfd, 600V	600-1012	Centralab D6-302
C244	Capacitor, paper, metalized, .15μfd, 100V ±5%	630-1015	Midwec 7F
C245	Capacitor, paper, metalized, .3μfd, 100V ±5%	630-1018	Midwec 7F
C246	Same as C244		
C247 & C248	Same as C212		
C249 & C250	Capacitor, ceramic, disc, .002μfd, 1000V	610-1006	Centralab DD-202
C251	Same as C212		
C252	Capacitor, paper, metalized .1μfd, 200V	630-1002	Hopkins P12D
C253 & C254	Capacitor, tantalum, 3.3μfd, 35V	632-1012	Sprague 150D335X 9035BO
C255	Same as C249		
C256	Capacitor, ceramic, GMV, 220μμfd, 600V	600-1003	Centralab D6-221
C257	Capacitor, paper, mylar, .1μfd, 600V	621-1004	Sprague 6PS-P10
C258	Same as C212		
C259 thru C400	Not assigned		
C401 & C402	Capacitor, electrolytic, 1000μfd, 16V	635-1025	Whale 30-625-1000 16-6PC
C403 thru C600	Not assigned		
C601A&B	Capacitor, electrolytic, 250-250μfd, 50V	635-1016	Sprague D7-1685
C602	Not assigned		
C603	Same as C211		
C604	Same as C401		
CR1 thru CR100	Not assigned		
CR101#	Diode 1N2482	101-2000	Sarkes 1N2482
CR102 thru CR200	Not assigned		
CR201	Diode, 1N816	101-2003	Transitron 1N816
CR202	Not assigned		
CR203	Diode, zener, VR6A	101-2009	Sarkes VR6A
CR204 thru CR220	Not assigned		
CR221 & CR222	Diode, ED90	101-2007	Erie ED90

#Used in Model MV-964A only

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
CR223 thru CR600	Not assigned		
CR601 & CR602	Diode, 1N2482	101-2000	Sarkes 1N2482
DS1 thru DS100	Not assigned		
DS101	Lamp, pilot AC	800-3003	Int. Products R6
F1 thru F100	Not assigned		
F101	Fuse, cartridge, S-B, 3/10 Amp	800-1006	Buss-MDL
G1 thru G200	Not assigned		
G201	DC Modulator, electro-mechanical, SPDT, 94Hz	700-1008	
J1 thru J100	Not assigned		
J101 & J102	Connector, BNC, female, INPUT	800-7030	UG-657/U
J103	Connector, amphenol, OUTPUT	800-6060	Amphenol 80PC2P
J104	Connector, POWER, male, 3-Pin	800-7406	Tower H1061
M1 thru M100	Not assigned		
M101	Meter, indicating, 0-500μA (MV-864A)	203-1115	
M101#	Meter, indicating, 0-500μA (MV-964A)	203-1120	
P1 thru P103	Not assigned		
P104	Cord set, line, power, removable	800-5121	Belden 17258S
P105	Part of P104		
Q1 thru Q200	Not assigned		
Q201	Transistor, Si, NPN, U183	100-1012	
Q202 & Q203	Transistor, Ge, PNP, 2N414	100-1004	Industro 2N414
Q204 thru Q210	Not assigned		
Q211 thru Q213	Same as Q202		
Q214	Transistor, Ge, PNP, 2N1414	100-1008	GE 2N1414

#Used in Model MV-964A only

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
Q215 & Q216	Same as Q214		
Q217 & Q218	Transistor, Ge, PNP 2N1373	100-1015	T.I. 2N1373
Q219	Same as ~~Q202~~ 2N 1414		
Q220 thru Q223	Same as Q214		
Q224 thru Q600	Not assigned		
Q601	Transistor, Ge, PNP, MHT 3030	100-1016	Solotron MHT3030
Q602	Transistor, Si, RA1	100-1010	GE RA1
R1 thru R100	Not assigned		
R101	Resistor, fxd, metal film, 10M ±1%, 1/2W	513-1005	
R102	Resistor, fxd, metal film, 3M ±1%, 1/2W	513-3004	
R103	Resistor, fxd, metal film, 2M ±1%, 1/2W	513-2004	
R104	Resistor, fxd, metal film, 667K ±1%, 1/4W	512-6673	
R105	Resistor, fxd, metal film, 200K ±1%, 1/4W	512-2003	
R106	Resistor, fxd, metal film, 66K ±1%, 1/4W	512-6602	
R107	Resistor, fxd, metal film, 20K ±1%, 1/4W	512-2002	
R108	Resistor, fxd, metal film, 6.7K ±1%, 1/4W	512-6701	
R109	Resistor, fxd, metal film, 2K ±1%, 1/4W	512-2001	
R110 & R111	Not assigned		
R112A	Resistor, var, carbon, linear taper, 3.5K ±20%, 1/2W ("FSΩ" Part of dual control)	580-1056	
R112B	Resistor, var, carbon, linear taper 1M ±20%, 1/4W ('ZERO' Part of dual control)	580-1056	
R113	Resistor, var, carbon, linear taper, 5K ±30%, 1/4W	580-1011	
R114 thru R200	Not assigned		
R201 & R202	Resistor, fxd, metal film, 400K ±1%, 1/4W	512-4003	
R203*	Resistor, fxd, metal film, 564.6K ±1%, 1/4W	512-56462	
R204*	Resistor, fxd, metal film, 330K ±1%, 1/4W	512-3303	
R205*	Same as R203		
R206	Resistor, fxd, metal film, 100K ±1%, 1/4W	512-1003	
R207 thru R209	Not assigned		
R210**	Resistor, fxd, metal film, 564.6K ±1%, 1/4W	512-56462	
R211	Resistor, fxd, metal film, 6K ±1%, 1/4W	512-6001	
R212	Resistor, fxd, WW, 70Ω ±1%, 1/2W	508-70R0	
R213	Not assigned		

*Resistor may be shunted by another resistor; value selected in manufacture

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R214	Resistor, fxd, metal film, 600Ω ±1%, 1/4W	512-6000	
R215	Resistor, fxd, metal film, 10K ±1%, 1/4W	512-1002	
R216	Resistor, fxd, metal film, 22K ±1%, 1/4W	512-2202	
R217	Resistor, fxd, metal film, 3.33K ±1%, 1/4W	512-3331	
R218	Resistor, fxd, metal film, 400Ω ±1%, 1/4W	512-4000	
R219	Resistor, fxd, composition, 10K ±10%, 1/2W	500-103	
R220	Resistor, fxd, composition, 22K ±10%, 1/2W	500-223	
R221	Resistor, fxd, composition, 3.3K ±10%, 1/2W	500-332	
R222	Resistor, fxd, composition, 390Ω ±10%, 1/2W	500-391	
R223 thru R237	Not assigned		
R238	Resistor, var, carbon, linear taper, 10K ±30%, 1/4W	580-1049	
R239	Resistor, fxd, composition, 2K ±10%, 1/2W	500-202	
R240	Resistor, fxd, composition, 1K ±10%, 1/2W	500-102	
R241	Resistor, fxd, composition, 1M ±10%, 1/2W	500-105	
R242 & R243	Same as R219		
R244	Resistor, fxd, composition, 82K ±10%, 1/2W	500-823	
R245	Same as R221		
R246*	Resistor, fxd, metal film, 12K ±1%, 1/4W	512-1202	
R247*	Resistor, fxd, metal film, 6K ±1%, 1/4W	512-6001	
R248*	Same as R246		
R249	Same as R219		
R250	Same as R244		
R251	Same as R219		
R252	Same as R240		
R253 & R254	Resistor, fxd, WW, 8.2Ω ±10%, 1W	510-8R2	
R255	Resistor, fxd, composition, 47Ω ±10%, 1/2W	500-470	
R256	Resistor, fxd, composition, 4.7K ±10%, 1/2W	500-472	
R257A	Resistor, var WW, linear taper, 75Ω ±20%, 2W	580-1055	
R257B*	Resistor, fxd, metal film, 150Ω ±1%, 1/4W	512-1500	
R258 & R259	Same as R109		
R260	Resistor, fxd, composition, 27Ω ±10%, 1/2W	500-270	
R261	Resistor, fxd, composition, 8.2K ±10%, 1/2W	500-822	
R262 & R263	Same as R240		
R264 & R265	Resistor, fxd, WW, 2.2Ω ±10%, 1W	510-2R2	
R266	Same as R255		
R267	Same as R256		
R268 & R269	Resistor, fxd, composition, 27K ±10%, 1/2W	500-273	

*Resistor may be shunted by another resistor; value selected in manufacture

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R270 & R271	Same as R244		
R272	Same as R260		
R273	Same as R256		
R274 thru R400	Not assigned		
R401	Resistor, fxd, metal film, 27M ±1%, 1W	532-2705	
R402	Same as R101		
R403	Resistor, fxd, metal film, 60M ±1%, 2W	542-6005	
R404	Resistor, fxd, metal film, 100M ±1%, 2W	542-1006	
R405	Resistor, fxd, metal film, 1M ±1%, 1/4W	512-1004	
R406	Resistor, fxd, metal film, 1.33M ±1%, 1/4W	512-1334	
R407	Resistor, fxd, metal film, 450K ±1%, 1/4W	512-4503	
R408 thru R410	Not assigned		
R411	Resistor, var., WW, linear taper, 25Ω ±20%, 2W	580-1058	
R412**	Resistor, fxd, WW, 8.2Ω ±10%, 1W	510-8R2	
R413**	Resistor, fxd, WW, 12Ω ±10%, 1W	510-120	
R414	Resistor, fxd, WW, 1Ω ±10%, 1W	510-1R0	
R415	Resistor, fxd, WW, 10Ω ±1%, 1/2W	508-10R0	
R416	Resistor, fxd, metal film, 100Ω ±1%, 1/4W	512-1000	
R417	Resistor, fxd, metal film, 1K ±1%, 1/4W	512-1001	
R418	Resistor, fxd, metal film, 10K ±1%, 1/4W	512-1002	
R419	Same as R206		
R420	Same as R405		
R421	Resistor, fxd, carbon film, 5M ±1%, 1/2W	520-5004	
R422	Resistor, fxd, carbon film, 50M ±1%, 2W	541-5005	
R423	Resistor, fxd, carbon, 500M ±10%, 1W	528-5006	
R424	Not assigned		
R425	Same as R405		
R426	Same as R101		
R427	Same as R404		
R428	Resistor, fxd, metal film, 500Ω ±1%, 1/4W	512-5000	
R429	Same as R211		
R430	Resistor, fxd, metal film, 60K ±1%, 1/4W	512-6002	
R431	Resistor, fxd, metal film, 600K ±1%, 1/4W	512-6003	
R432	Resistor, fxd, metal film, 250K ±1%, 1/4W	512-2503	
R433	Resistor, fxd, carbon film, 2.5M ±1%, 1/4W	518-2504	
R434	Resistor, fxd, metal film, 20M ±1%, 1/2W	513-2005	
R435	Same as R421		
R436 thru R440	Not assigned		
R441	Resistor, fxd, metal film, 3.3K ±1%, 1/4W	512-3301	
R442	Resistor, fxd, metal film, 333Ω ±1%, 1/4W	512-3330	

**Selected in manufacture; nominal value listed

Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R443	Resistor, fxd, metal film, 33.3Ω ±1%, 1/4W	512-33R3	
R444*	Resistor, fxd, WW, 3.33Ω ±1%, 1/2W	512-3R33	
R445*	Resistor, fxd, WW, 1Ω ±1%, 1/2W	508-1R00	
R446*	Resistor, fxd, WW, .333Ω ±10%, 1/2W	507-R333	
R447**	Resistor, fxd, WW, 0.1Ω ±10%, 1/2W	507-R10	
R448**	Resistor, fxd, WW, .033Ω ±10%, 1/2W	507-R033	
R449**	Resistor, fxd, WW, .01Ω ±10%, 1/2W	507-R01	
R450 & R451	Not assigned		
R452	Resistor, fxd, metal film, 2K ±1%, 1/4W	512-2001	
R453#	Resistor, fxd, metal film, 28K ±1%, 1/4W	512-2802	
R454 thru R500	Not assigned		
R501	Resistor, var., carbon, linear taper, 200K ±30%, 1/4W	580-1050	
R502	Resistor, var., carbon, linear taper, 50K ±30%, 1/4W	580-1021	
R503	Resistor, var., carbon, linear taper, 10K ±30%, 1/4W	580-1049	
R504	Resistor, var., carbon, linear taper, 2K ±30%, 1/4W	580-1051	
R505	Resistor, var., carbon, linear taper, 500Ω ±30%, 1/4W	580-1022	
R506 & R507	Same as R504		
R508	Resistor, var., carbon, linear taper, 1K ±30%, 1/4W	580-1024	
R509 thru R515	Same as R505		
R516 thru R518	Same as R503		
R519	Same as R504		
R520 & R521	Same as R505		
R522 thru R525	Same as R508		
R526**	Resistor, fxd, metal film, 750K ±1%, 1/4W	512-7503	
R527**	Resistor, fxd, metal film, 226K ±1%, 1/4W	512-2263	
R528**	Resistor, fxd, metal film, 66K ±1%, 1/4W	512-6602	
R529**	Resistor, fxd, metal film, 17.7K ±1%, 1/4W	512-1772	
R530** & R531**	Same as R529		
R532**	Resistor, fxd, metal film, 9K ±1%, 1/4W	512-9001	
R533** thru R535**	Same as R528		
R536**	Same as R529		
R537**	Resistor, fxd, metal film, 1.5K ±1%, 1/4W	512-1501	

*Resistor may be shunted by another resistor; value selected in manufacture
**Selected in manufacture; nominal value listed
#Used in Model MV-964A only

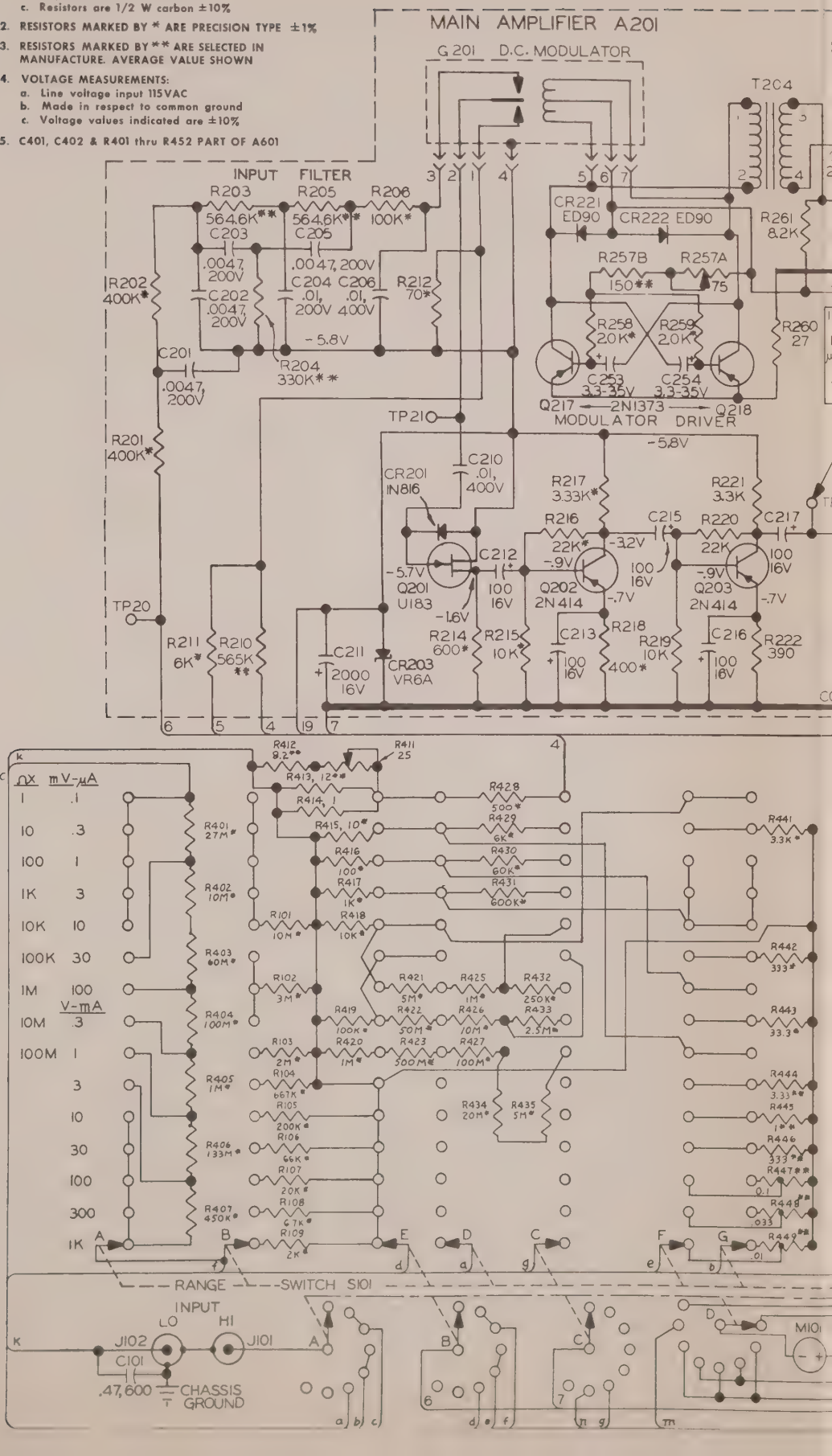
Ckt Sym	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R538 thru R600	Not assigned		
R601	Resistor, fxd, WW, 1Ω ±10%, 1W	510-1R0	
R602	Same as R601		
R603	Resistor, fxd, WW, 25Ω ±10%, 10W	560-1002	
R604 & R605	Same as R256		
R606	Resistor, fxd, metal film, 1.5K ±1%, 1/4W	512-1501	
R607	Same as R508		
R608	Same as R606		
R609 & R610	Not assigned		
R611 & R612	Resistor, fxd, composition, 270Ω ±10%, 1/2W	500-271	
R613	Resistor, fxd, WW, 68Ω ±10%, 1W	510-680	
RT1 thru RT100	Not assigned		
RT101#	Lamp, 'Ballast'	110-3003	CM239
S1 thru S100	Not assigned		
S101	Switch, rotary, Range	410-1035	
S101	Switch, rotary, Range (complete ass'y.)	420-1035	
S102	Switch, rotary, Function (MV-864A)	410-1036	
S 102	Switch, rotary, Function (Complete ass'y)(MV-864A)	420-1036	
S102#	Switch, rotary, Function (MV-964A)	410-1037	
S102#	Switch, rotary, Function (Complete ass'y)(MV-964A)	420-1037	
S103	Switch, slide, DPDT, Line Voltage	400-1015	
T1 thru T201	Not assigned		
T202	Transformer, interstage	300-2008	
T203	Same as T202		
T204	Transformer, interstage	300-2007	
T205 & T206	Same as T202		
T207 thru T600	Not assigned		
T601	Transformer, power	300-4010	
	MISCELLANEOUS		
	Cap, shorting	800-7020	Amphenol CW159/U
	Fuseholder	800-2100	Buss HKP
	Knob, bar, with skirt, Range Switch	800-4128	Buckeye PS-95BL-S2
	Knob, bar, Function Switch	800-4137	Buckeye PS-70BL-2
	Knob, 'Zero'	800-4134	Buckeye PS-50-D-3
	Knob, 'F.S.Ω'	800-4135	Buckeye 70-C-5
	Test Lead Set (2)	UG-201	
	Test Lead Set	CL-102	

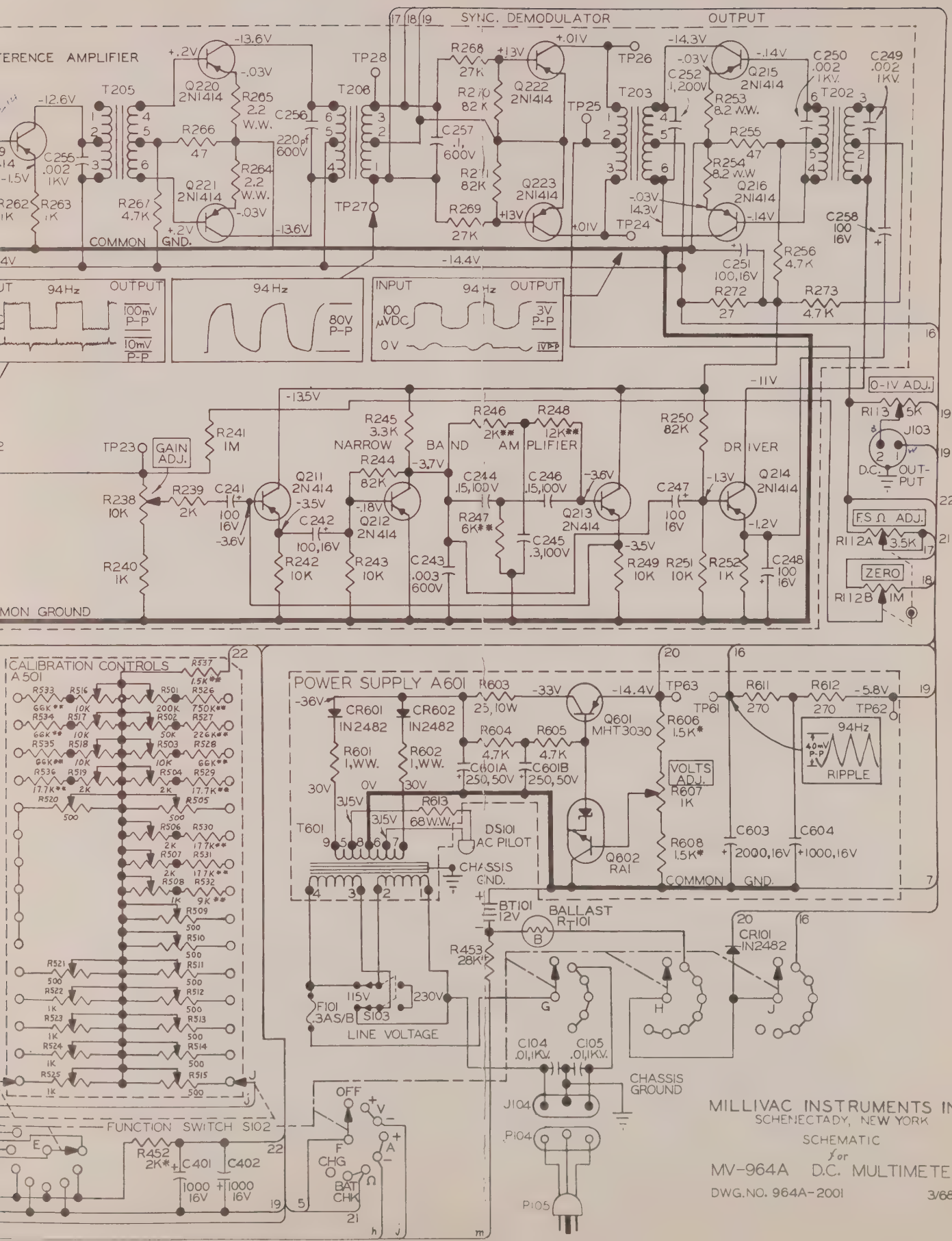
#Used in Model MV-964A only

1-864A-2001
1-964A-2001

NOTES

1. UNLESS OTHERWISE SPECIFIED:
   a. Resistor values are in ohms
   b. Capacitor values are in ufd
   c. Resistors are 1/2 W carbon ±10%
2. RESISTORS MARKED BY * ARE PRECISION TYPE ±1%
3. RESISTORS MARKED BY ** ARE SELECTED IN MANUFACTURE. AVERAGE VALUE SHOWN
4. VOLTAGE MEASUREMENTS:
   a. Line voltage input 115VAC
   b. Made in respect to common ground
   c. Voltage values indicated are ±10%
5. C401, C402 & R401 thru R452 PART OF A601




SYNC. DEMODULATOR OUTPUT
TERENCE AMPLIFIER
COMMON
GND.
-14.4V
94Hz OUTPUT
100mV P-P
10mV P-P
94Hz
80V P-P
INPUT 94Hz OUTPUT
100 µVDC
0V
3V P-P
1VP-P
GAIN ADJ.
NARROW BAND AMPLIFIER
DRIVER
0-1V ADJ.
D.C. OUTPUT
F.S Ω ADJ.
ZERO
COMMON GROUND
CALIBRATION CONTROLS A501
POWER SUPPLY A601
VOLTS ADJ.
94Hz RIPPLE
DS101 AC PILOT
CHASSIS GND.
BALLAST RT101
LINE VOLTAGE
115V
230V
F101 .3AS/B
S103
FUNCTION SWITCH S102
OFF
CHG
BAT CHK
CHASSIS GROUND
J104
P104
P105
MILLIVAC INSTRUMENTS INC.
SCHENECTADY, NEW YORK
SCHEMATIC
for
MV-964A D.C. MULTIMETER
DWG.NO. 964A-2001
3/68

GUARANTEE

Millivac Instruments, Inc. guarantees each instrument manufactured by us to be free from defects in material and workmanship for a period of one year from date of delivery to the original purchaser. Repairs during this time will be made by us free of charge, but transportation charges both ways will be borne by the customer.

Excluded from this guarantee are tube and transistor replacements, as well as all damages caused by, or related to, abuse of the instrument either electrically or mechanically. In this case, repairs will be billed at cost and an estimate will be submitted for your approval before the work is started.

If an instrument is believed to be defective, please notify our Service Department, giving the model number and serial number of the instrument, as well as describing the nature of the trouble. Our Service Department will then, if necessary, authorize the return of the instrument under the terms of this guarantee and advise how shipment should be made.

CLAIM FOR DAMAGE IN SHIPMENT

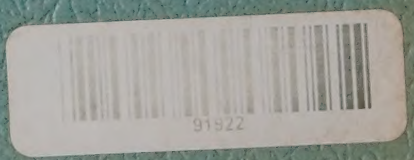
If, on receipt, the shipping cartons appear to be crushed or torn, as evidencing rough treatment, a notation should be made on the carrier's delivery receipt indicating this condition.

As each item is opened, it should be inspected to ascertain that no damage has been incurred during shipment. If no damage is visible, operational checks should be performed to make sure that the equipment arrives in its original operating condition. If any damage is revealed, a claim should be filed immediately with the carrier, stating the extent of the damage. A copy of this report should be forwarded to us along with the model and serial number of the instrument. Millivac will then advise how the instrument should be returned for repair or replacement.

SHIPPING INSTRUCTIONS FOR RETURNS TO FACTORY

No instrument should be returned to the factory without prior authorization from Millivac Instruments, Inc. or our authorized representative.

Shipping instructions will be given at the time return of an instrument is authorized. In all cases the instrument should be packed in a strong container and surrounded by sufficient shock-absorbing material.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